



An SLR Receiver to discriminate Single- from Multiphoton Events

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Abstract

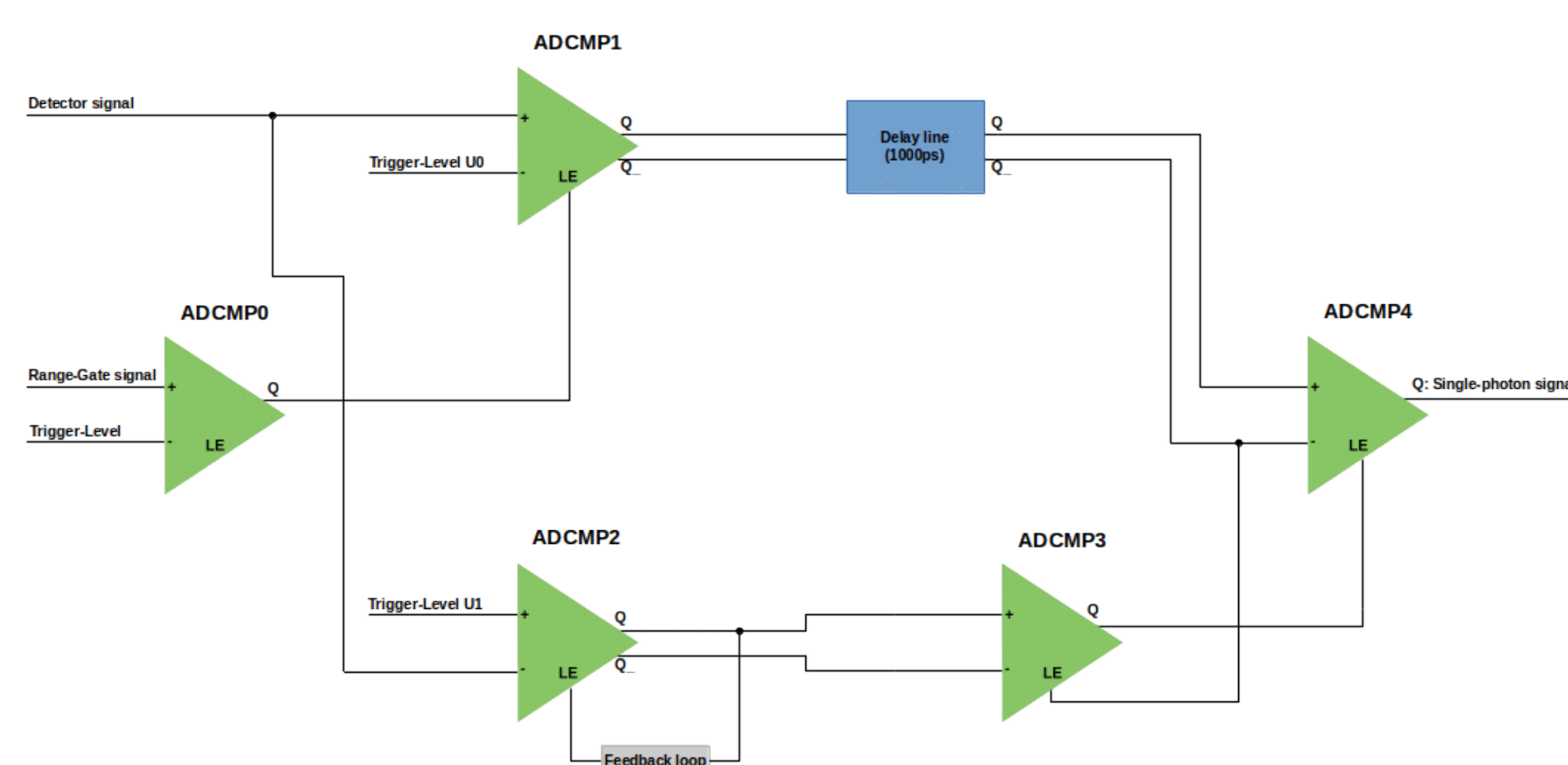
In Satellite Laser Ranging the distance to satellites is determined by laser pulse time-of-flight measurements. To minimize systematic errors in the measurements usually time-correlated single photon counting is applied. This method provides a high dynamic range as long as the signal is kept at the single photon level. Higher signal levels introduce systematic errors. Assuming a Poisson distributed signal, which is valid for a coherent light source such as a laser, the single photon level can be reached at a detection rate of below 10 percent. In Satellite Laser Ranging, however, laser pulses are sent through the turbulent atmosphere. This leads to speckle formation at the satellite and at the ground side. The resulting scintillation leads to fluctuations in the intensity of the received signal. This may introduce systematic errors in the measurement. To investigate the effects of signal strength fluctuations on the accuracy of SLR measurements, we built a photon number sensitive receiver. The receiver allows to discriminate single-from multi-photon events. We want to give an overview of the technical details of this receiver.

Printed Circuit Board design and schematic

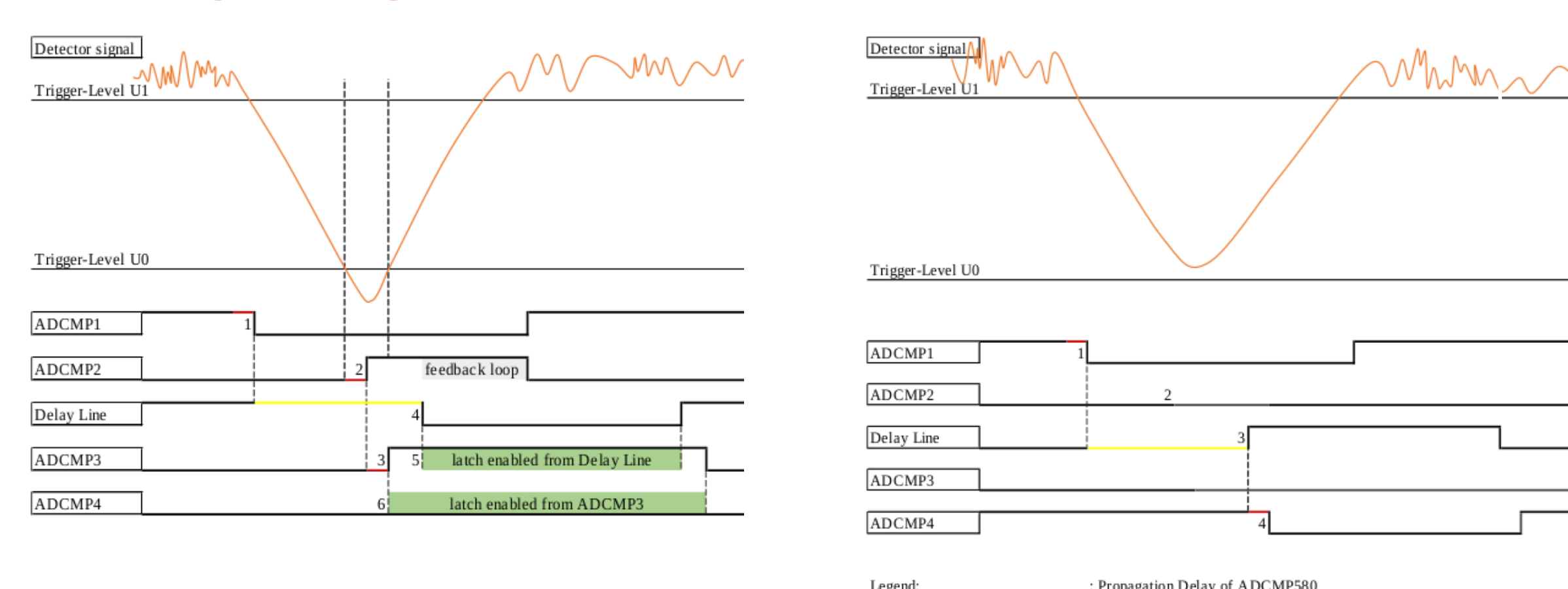
Ultra-high-speed discriminator circuit with lowest temperature dependence to analyze the effect of scintillation on SLR measurements by filtering out multi-photon seeded pulses

Main components:

- | | |
|------------------------------|-----------------------------|
| ADCMP580 as comparators: | 2x MAX9600 as a delay line: |
| • Propagation delay: 180ps | • Propagation delay: 500ps |
| • Random jitter: 200fs | • Output jitter: 300fs |
| • Deterministic jitter: 10ps | |



Timing diagram



Case 1 (right hand side)

- 1) ADCMP1 detects the falling edge of the pulse.
- 2) ADCMP2 detects the pulse under the adjusted trigger level (a feedback loop extends the signal to avoid misalignments).
- 3) ADCMP3 switches in high level because of ADCMP2.
- 4) Two MAX9600 act as a delaying element for the signal of ADCMP1.
- 5) The latch mode of ADCMP3 is enabled by the delayed signal of the second MAX.
- 6) The latch of ADCMP4 is enabled by the signal of ADCMP3 right before the signal of the delay element would switch the output low. According to that ADCMP4 is latched while the signal of the delay line passes the input. The output remains high for case 1.

Case 2 (left hand side)

- 1) ADCMP1 detects the falling edge of the pulse.
- 2) ADCMP2 detects no pulse and hence ADCMP3 and ADCMP4 remain in compare mode.
- 3) Two MAX9600 act as a delaying element for the signal of ADCMP1.
- 4) ADCMP4 is in compare mode and switches to low level. The output signal is the single-photon seeded pulse, which can be detected by the event timer.

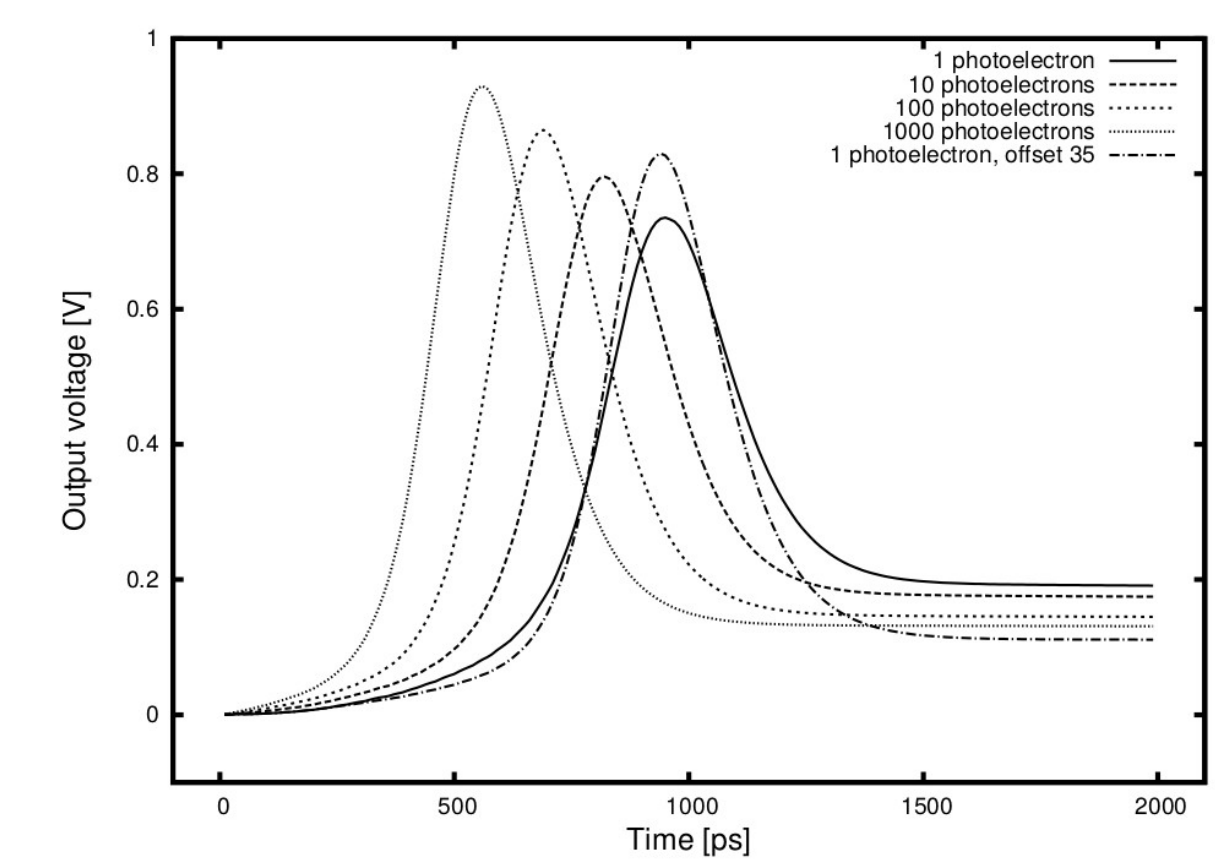
Single-photon receiver and its output

SPAD (Single Photon Avalanche Diode):

The quenching circuit of the SPAD permits a peak output voltage depending on the detected photons.

Photomultiplier:

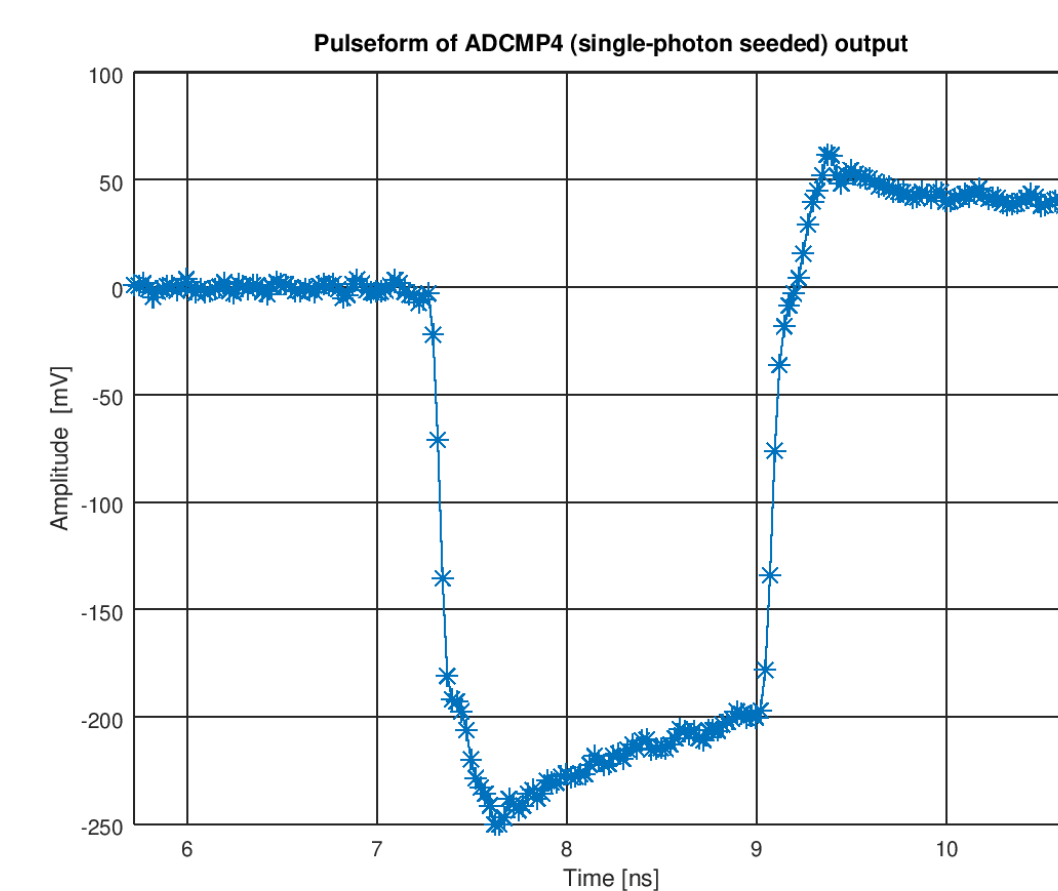
A photomultiplier is a linear detector, which means that the peak output voltage of the detector has a linear dependence on the impinging signal strength.



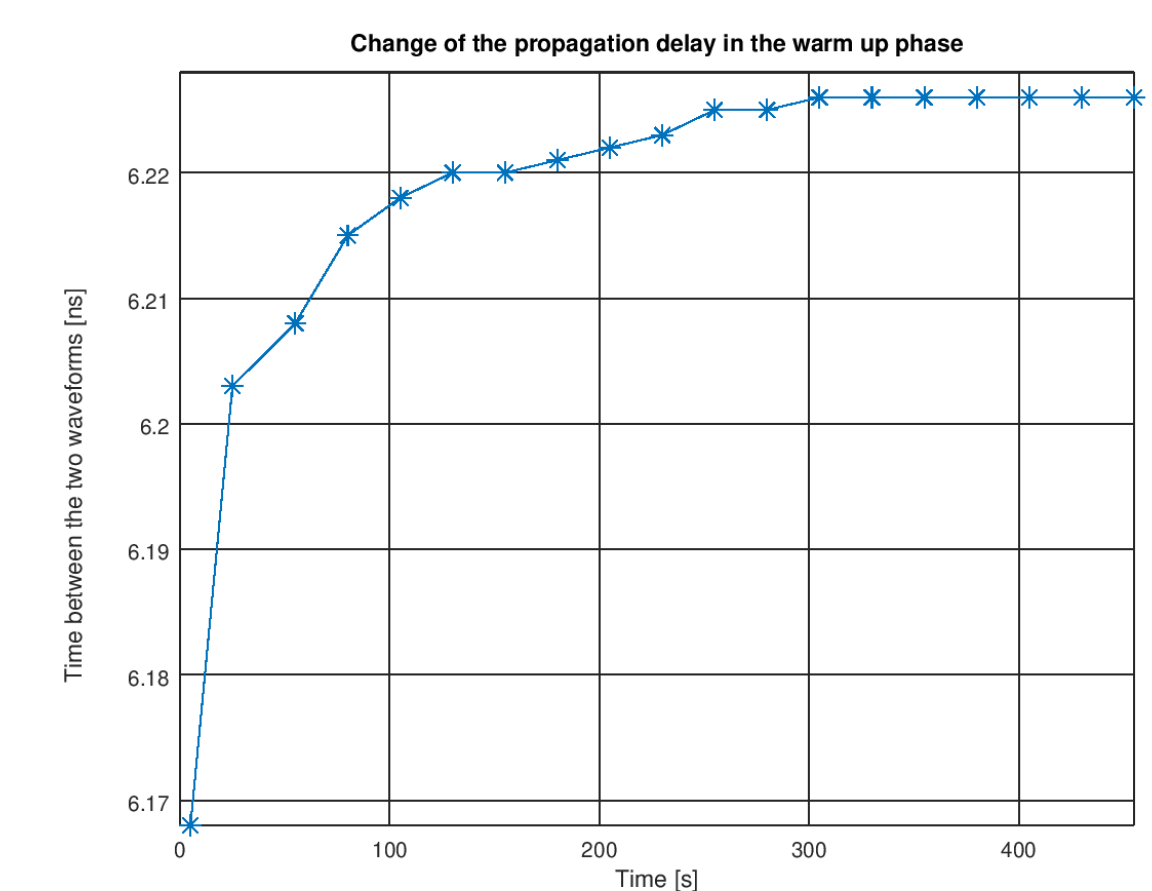
SPAD output voltage depending on single- or different multiphoton events

(source: Johann Eckl, Investigation of Intensity Dependent Time Delays of InGaAs/InP Single Photon Avalanche Diodes for Satellite Laser Ranging Applications in the Infrared Regime)

Measurements

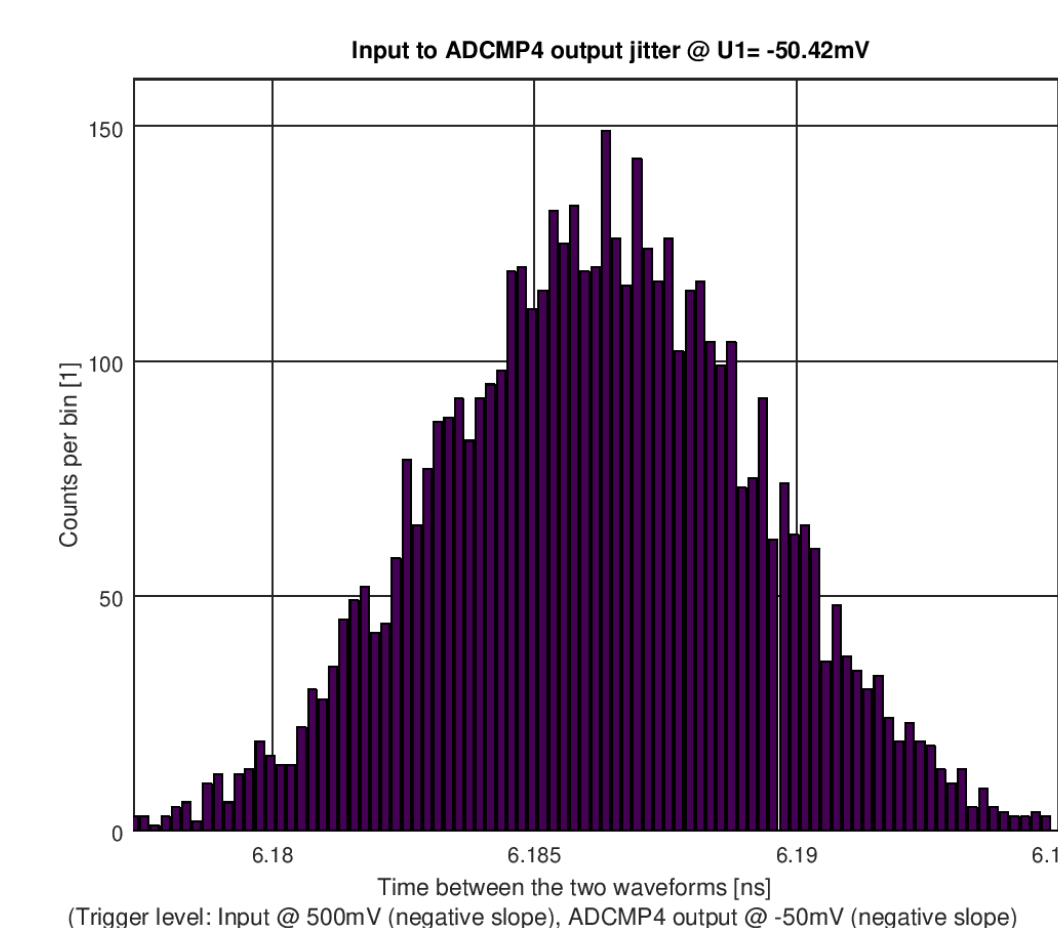


Pulse shape of the output, rise time: 400ps

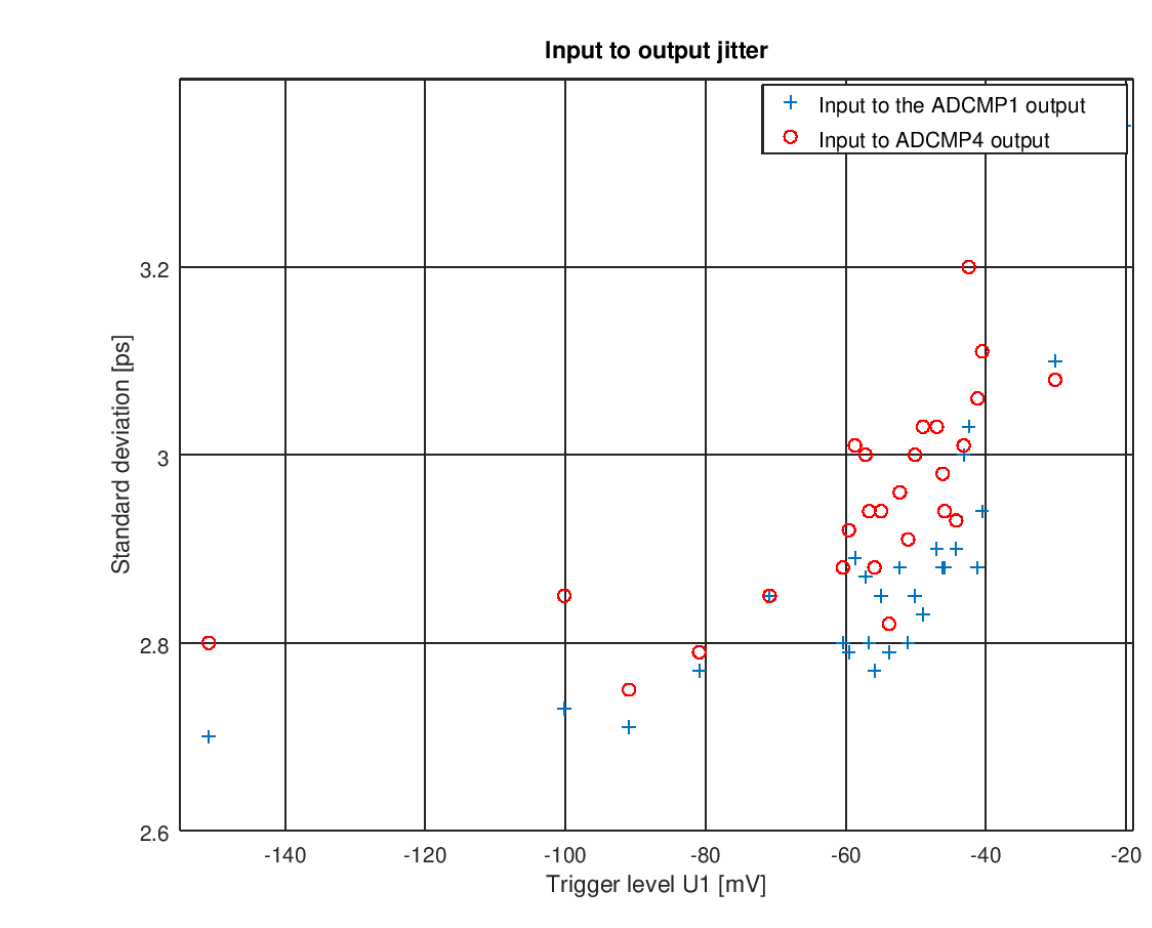


Warm up process finished after 300 sec

Jitter of the discriminator board



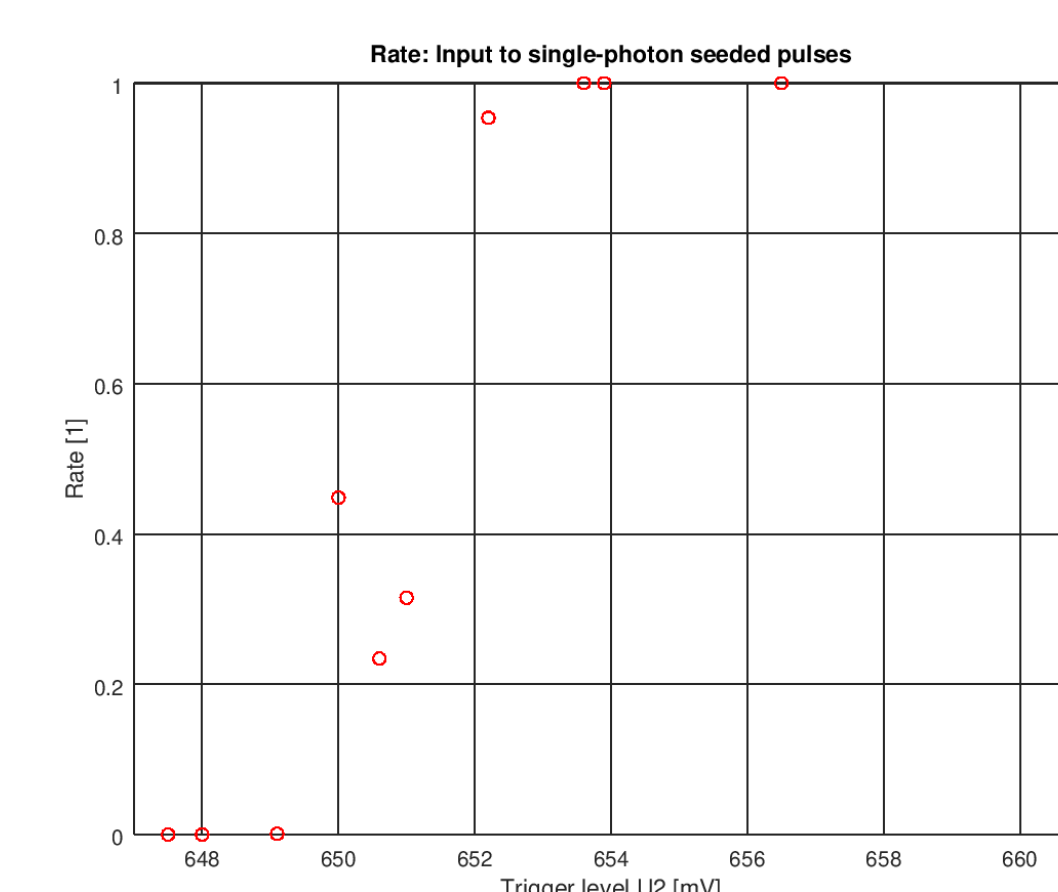
Histogram of the input to single-photon seeded pulses output (@U1 = -50.42mV), standard deviation: 3ps



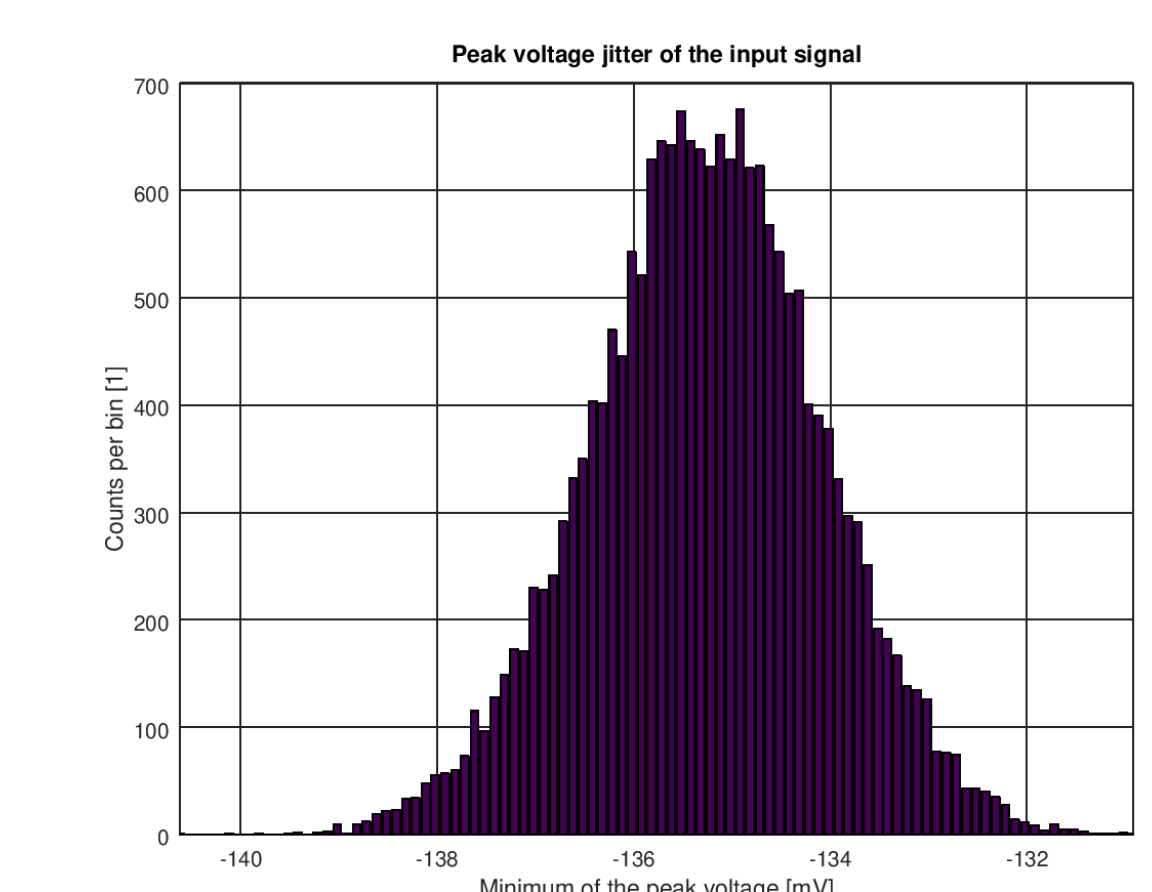
Standard deviation of the input to output jitter depending on the trigger level U1

Filter performance

Considering the rate of input pulses to output pulses gives a feedback about the quality of the pulse discrimination. In an ideal case there would be a defined cut of a 100% and a 0% transition rate. Because of the jitter behaviour of the input signal with a standard deviation of about 2mV and FWHM of 4mV the transition rate should also represent this jitter in this case.



Transition rate of the single-photon seeded pulse discrimination, commuted in 5mV



Jitter in the peak output voltage of the Digital Delay Generator and Fast Rise Time Module, standard deviation: 2mV

The transition rate of the discriminator board represents the jitter of the generated input signal.

Outlook

- Testing the discriminator circuit in real measurement
- Analyze the effect of scintillation on the measurement technique
- Derive methods to achieve sub-mm accuracy and precision in SLR